NICE³
Success Story

REAL-TIME NEURAL NETWORKS FOR UTILITY BOILERS

NICE³

Real-Time Neural Networks for Combustion Optimization of Utility Boilers Reduce Emissions

Benefits

◆ Reduces need for new power plants for utility expansion projects, thus reducing associated impacts on land and water

◆ Improved heat rate means more electricity is produced per unit of CO_2 and SO_X emitted

◆ Reduces NO_X emissions by 20% to 60% while maintaining or improving plant thermal efficiency and reducing SO_X and CO_2 emission levels

◆ Has saved 6.2 trillion Btu in 2000 from 31 operating systems

◆ Has saved 20.4 trillion Btu and more than $35 million in energy costs cumulatively through 2000
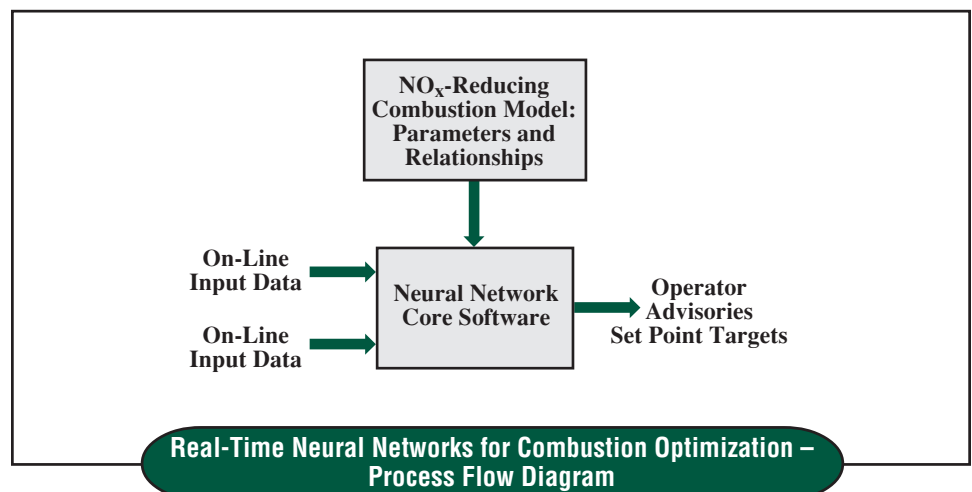
Applications

Real-time neural networks can be used by coal-, oil-, and gas-fired boilers, particularly those with capacities of 25 MW or greater.

Three major air pollutants from power plants are nitrogen oxide (NO_X), sulfur dioxide (SO_2), and carbon dioxide (CO_2). The U.S. Environmental Protection Agency (EPA) has identified NO_X and SO_2 as contributors to smog, health problems, and acid rain and has issued regulations to control NO_X and SO_2 emissions. CO_2 is thought to be the major cause of global climate change.

A new technology is helping utilities cut costs related to reducing emissions from coal-fired electric power plants. Pegasus Technologies Inc. of Mentor, Ohio, has developed the NeuSIGHT system to cut NO_X, SO_2, and CO_2 emissions. The NeuSIGHT system, which employs closed-loop supervisory control in real time, can improve power plant operation by increasing operating efficiency and reducing emissions.

According to Willie Roland, Pegasus' project manager, "Reduced emissions and higher operating efficiency are becoming increasingly important in the utility sector. We have integrated the latest advances in artificial intelligence, sensors, and control technologies into a system that allows utilities to automatically fine-tune operation of their power plants to both reduce emissions and improve performance. And NeuSIGHT does it very cost-effectively."

Pegasus has found that its system reduces NO_X emissions from coal-fired power plants by the same amount as a low-NO_X burner retrofit on some units. Low-NO_X burner retrofits cost approximately $5 million for a large coal-fired power plant–twenty times the cost of the NeuSIGHT system.

NO_X-Reducing Combustion Model: Parameters and Relationships

On-Line Input Data → Neural Network Core Software → Operator Advisories Set Point Targets

On-Line Input Data →

Real-Time Neural Networks for Combustion Optimization – Process Flow Diagram

Funding for a Cost-Competitive Future

In 1994 Pegasus received a $100,000 grant under the U.S. Department of Energy's (DOE's) NICE³ (National Industrial Competitiveness through Energy, Environment, and Economics) Program to modify its heat rate improvement advisory system to include closed-loop supervisory control for reducing NO_X and improving heat rates. Pegasus combined the NICE³ grant with its own investment to develop and demonstrate an integrated system that allows real-time responses to reduce pollutant emissions. Ohio Edison and the Ohio Department of Development's Office of Energy Efficiency also contributed funds to the project.

Improved Control Systems

Advances in computer technology and the science of neural networks and other artificial intelligence technologies made it possible for Pegasus to develop "smart" controls to reduce emissions at the source. Instead of using traditional linear models, this system applies nonlinear models that rapidly analyze "what-if" situations with as many as 120 variables. These analyses determine the appropriate combustion set points needed to reduce emissions to the desired level.

The NeuSIGHT system carries the "smart" control one step further–the models automatically update themselves based on information learned from power plant boiler operation. "The real advantage of neural networks," noted Roland, "is that they are interactive and permit real-time responses." The networks use a pattern-recognition method that allows the system to adjust quickly to real-time operations rather than relying on rigid methods based on textbook calculations or static models.

For power plants without existing emissions controls, Pegasus estimates that its system will reduce NO_X emissions by 20% to 60% (typically 25% to 35%). When NeuSIGHT is added, plants that have already been fitted with low-NO_X burners typically experience a further reduction of 10% to 40% in NO_X emissions. One NeuSIGHT system installed in a power plant with low-NO_X burners achieved NO_X levels as low as 0.13 lb/million Btu. In addition, improved heat rate means that more electricity is produced per unit of CO_2 and SO_2 emitted, so emissions of these pollutants decrease as well. Pegasus has estimated that its system can improve heat rate from 0.5% to 5%, which translates into an equivalent reduction in CO_2 and SO_2 emissions. According to Roland, "The NICE³ grant allowed us to add the key emissions control capability to our system. Once the utilities saw that it worked with minimum maintenance costs, they were willing to start placing their orders."

Demonstrated Sales Success and Recognition

In October 1995 Ohio Edison fired up its first NeuSIGHT system, installed on a vintage 145-megawatt (MW) coal-fired plant. The system reduced NO_X emissions about 15% at full load and as much as 60% at low load. The overall unit heat rate improved 1.3%. The second system, installed on Dayton Power and Light's 650-MW Killen plant, was successfully demonstrated in 1997. After these demonstrations were successfully completed, sales began to take off. Pegasus has sold 37 units, of which 31 are still operating. These units are not only reducing air emissions but are also saving 0.2 trillion Btu/year per unit for a total of 6.2 trillion Btu/year.

GROSSGEN vs. Average O_2 Plot
Manual Control vs. Closed-Loop Supervisory Control
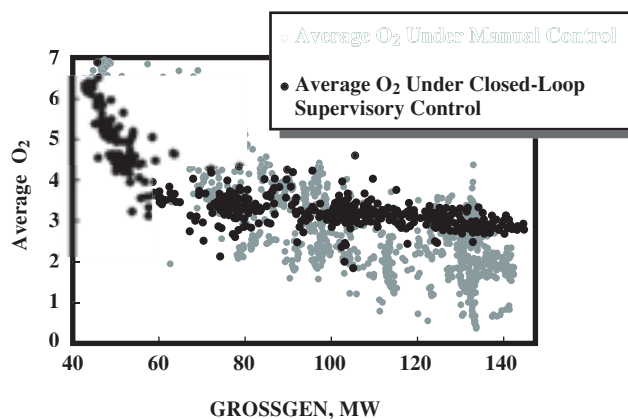
GROSSGEN vs. NO_X Plot
Manual Control vs. Closed-Loop Supervisory Control
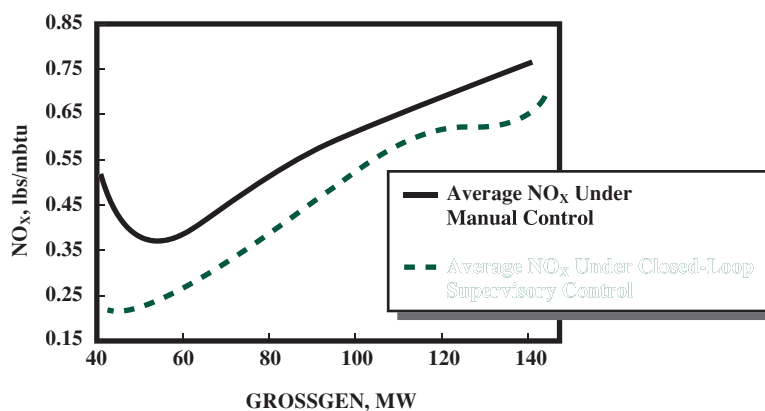
NeuSIGHT Optimizes Combustion and Lowers NO_X Emissions

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Table 1. *Estimated Annual Reductions from Efficiency Improvements (200 Installations)*

Fuel/Effluent	Reduction (tons/yr)
Coal Consumption	1.13 M*
CO_2 Emissions	4.68 M
NO_X Emissions	472,500
SO_2 Emissions	45,000
Particulates	6,200

* Saving 45 trillion Btu/yr.

With electric utility deregulation and tighter air quality regulations, Roland expects as many as 200 systems will be installed in power plants in the next five years. An average unit in the utility industry is 400 MW with a 60% capacity factor. With an improvement in efficiency of 1% and an NO_X reduction of 20%, the 200 installations would experience the reduced coal consumption and effluent emissions provided in Table 1.

Pegasus forecasts that 37% of the U.S.-pulverized coal plants and 25% of plants worldwide will use neural network systems by 2010. Additional environmental benefits will result from reduced coal-mining, transportation, processing, and combustion waste disposal.

System Economics and Market Potential

Pegasus estimates a simple 6-month to 1-year payback period based on reduced fuel consumption. In some cases investments in selective catalytic or noncatalytic reduction equipment needed to comply with required NO_X levels can be avoided or deferred, resulting in a large economic benefit.

An even broader market for the Pegasus technology includes optimized soot blowing, improved multivalve point turbine control, decreased electrostatic precipitator power usage, and decreased limestone usage in SO_2 scrubbers. The technology can also be vertically integrated for system-wide asset management supporting activities such as equipment diagnostics and maintenance, inventory management, and load dispatching. Other applications include industrial boilers in several industries: petroleum; chemical; pulp and paper; pharmaceutical; food and beverage; primary metal; plastic; textile; and stone, clay, and glass industries. Pegasus has conducted trial runs of the system installed on a boiler fueled with municipal solid waste– another potential market.

Pegasus has actively marketed the NeuSIGHT system. Publications about the system have appeared in several industry journals. Since successfully demonstrating the technology under the NICE[3] grant program, Pegasus has made more than 70 presentations and presented 14 conference papers on the system.

In recognition of the success of its innovative technology, Pegasus received DOE's Office of Industrial Technologies Commercialization Achievement Award in 1996 for its outstanding leadership in developing and commercializing a new combustion control technology.